UNCLASSIFIED

AD NUMBER
AD883327
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies only; Administrative/Operational Use; APR 1971. Other requests shall be referred to Air Force Weapons Lab., Kirtland AFB, NM 87117.**
AUTHORITY
AFWL ltr 1 May 1972

THIS PAGE IS UNCLASSIFIED

AD883327

AFWL-TR-71-23

AFWL-TR-71-23

2

MEASUREMENT OF PRESSURE, IMPULSE, AND DETONATION VELOCITY FOR DETASHEET L EXPLOSIVE

J. D. Colton

Stanford Research Institute

TECHNICAL REPORT NO. AFWL-TR-71-23

April 1971

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

Each transmittal of this document outside the agencies of the U. S. Government must have prior approval of AFWL (SRR), Kirtland AFB, NM, 87117.

AFWL-TR-71-23

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico 87117

AFWL-TR-71-23

MEASUREMENT OF PRESSURE, IMPULSE, AND DETONATION VELOCITY FOR DETASHEET L EXPLOSIVE

J. D. Colton

Stanford Research Institute

TECHNICAL REPORT NO. AFWL-TR-71-23

AFWL-TR-71-23

FOREWORD

This report was prepared by Stanford Research Institute, Menlo Park, California, under Contract F29601-69-C-0080. The research was performed under Program Element 61102H, Project 5710, Subtask AA122.

Inclusive dates of research were November 1970 through January 1971. The report was submitted 26 March 1971 by the Air Force Weapons Laboratory Project Officer, Captain David K. Miller (SRR), who along with James H. Suttle and Captain Ronald D. Schappaugh provided technical direction.

Detasheet D and Detasheet L are trade names. Their use does not imply recommendation by the Air Force or Stanford Research Institute over equivalent products made by other manufacturers.

The contractor report number is PYU 7850.

This technical report has been reviewed and is approved.

David K. Miller

DAVID K. MILLER
Captain, USAF
Project Officer

for John T Vila, Maj

DURWARD D. YOUNG, JR.
Lt Colonel, USAF
Chief, Radiation Effects Branch

Harry F. Rizzo

HARRY F. RIZZO
Lt Colonel, USAF
Chief, Radiation Division

ABSTRACT

(Distribution Limitation Statement No. 3)

Tests were conducted to measure the impulse and pressure characteristics of Detasheet L explosive. Results of these tests show a maximum detonation velocity of 7.6 mm/μsec, a minimum detonation thickness of 6 mils, a peak pressure in direct contact with silica phenolic (simulated by doped epoxy) of about 80 kbar, and a specific impulse of 755 ± 15 taps/mil. The minimum impulse generated by a continuous sheet of Detasheet L explosive is about 4500 taps compared with about 7800 taps (12 mils) for Detasheet D. The L explosive is considerably more difficult to roll into thin sheets (takes more passes) than Detasheet D explosive. However, this difficulty is associated with the stiffer binding material in the L explosive, which gives the compensating advantage that even in very thin sheets the L explosive has little tendency to stretch during handling. Thus, Detasheet L has its greatest advantage in very thin, dimensionally stable sheets for low impulse testing. It can also be used in thicker sheets for higher impulse testing, but at these levels the D explosive has the advantage of being easier to roll.

This page intentionally left blank.

CONTENTS

ILLUSTRATIONS

TABLES

SECTION I

INTRODUCTION

1. BACKGROUND AND OBJECTIVES

Sheet explosive has been used extensively to simulate radiation loads on the surface of reentry vehicles because it conveniently provides loads over the large curved area of a full reentry vehicle with no practical limit to the maximum impulse. However, the sheet explosive in most common use, Detasheet D (manufactured by Du Pont), has a minimum impulse corresponding to the minimum thickness of explosive required to propagate detonation. For Detasheet D this minimum thickness is about 12 mils; the corresponding impulse for the explosive in contact with typical heat shield materials is about 7800 taps. Since some simulation tests at threshold damage levels require a lower impulse, a stripped explosive loading configuration has been used, as described in reference 1. Unfortunately, this technique introduces nonuniformities in the load and is susceptible to inaccuracies caused by stretching of the strips during handling. A new explosive, Detasheet L (also manufactured by Du Pont), provides a lower minimum impulse from a continuous sheet because it can be detonated at smaller thicknesses. The objective of the present program is to evaluate this new explosive for use in simulation tests.

The physical characteristics of Detasheet L explosive are different than those of Detasheet D explosive. Detasheet L is tougher and stronger than Detasheet D and has a resilient quality which reduces its susceptibility to wrinkling during the rolling process and to stretching during handling. However, the time required to roll Detasheet L to a specified thickness is about three times that required for Detasheet D. The density of Detasheet L, measured at several thicknesses by the water displacement method, was found to be 1.56 gm/cm^3 compared to 1.40 gm/cm^3 for Detasheet D. Detasheet L is light gray in color.

Although measurements were made only on Detasheet L explosive in this program, existing data on Detasheet D (Ref. 1) are presented in this report for comparison.

2. PROGRAM

The characteristics of explosives of most interest in nuclear effects simulation work are detonation velocity, minimum detonation thickness, peak pressure, and impulse. Extensive measurements of these quantities have been made previously for Detasheet D (Ref. 1). In this program measurements of these quantities we made for Detasheet L. Since Detasheet D is satisfactory for simulation at thicknesses greater than 12 mils (7800 taps), Detasheet L will be used for simulation primarily when lower impulse levels, and therefore smaller explosive thicknesses, are required. Most of the tests on Detasheet L reported here were performed near its minimum detonation thickness.

SECTION II

RESULTS

1. DETONATION MEASUREMENTS

a. Experimental Technique

Detonation velocities were measured with a rotating mirror smear camera by photographing the explosive detonation front as it traveled 3.25 inches down a 1-inch-wide sheet of explosive. With this method the detonation front is viewed through a slit while the image of the slit is being swept across the film by the rotating mirror. The experimental procedure is described in more detail in reference 2.

b. Results

Results of the measurements of detonation velocity are given in Table I and shown graphically in Figure 1. They show that the maximum detonation velocity for Detasheet L is about 7.6 mm/µsec. The maximum detonation velocity for Detasheet D is 7.3 mm/µsec.

The minimum thickness for detonation of Detasheet L explosive was found to be 6 mils. Although detonation was complete for all tests performed with explosive greater than 6 mils thick, complete detonation of the Detasheet L explosive was unreliable with 5.5-mil-thick explosive, and 5-mil-thick explosive failed to detonate.

For tests of Detasheet L of thickness less than 20 mils, a 15-mil-thick Detasheet D lead-in was used to initiate detonation. Three tests were performed with 0.1-inch-wide strips of 6-mil-thick explosive. The explosive detonated every time, even around a 90-degree bend in the strip. Seven tests were performed with continuous sheets of 6-mil-thick explosive. In two of these tests the Detasheet D lead-in failed to initiate detonation at the edge of the Detasheet L. However, in the other five tests, detonation was complete.

Table I

DETONATION VELOCITY OF DETASHEET L EXPLOSIVE

Shot No.	Explosive Thickness (mils)	Detonation Velocity (mm/μsec)
S-9	6	7.19
S-8		7.25
S-7	8	7.41
S-6		7.42
S-4	10	7.43
S-15		7.53
S-13	25	7.56
S-14		7.62
S-10	125	7.68
S-11	168	7.58
S-12		7.63

2. PRESSURE MEASUREMENTS

a. Experimental Techniques

Pressure measurements were made with piezoresistive gages employing a sensing element made of manganin wire (originally 3 mils in diameter) flattened to 1 mil in thickness and 7 mils in width. This shape was selected to minimize the rise time of the gage.* The wire was in a π-pattern configuration embedded in epoxy doped with glass beads to match the shock impedance of silica phenolic as described in reference 1. In most tests, the standoff distance between the loaded surface and the wire was 10 mils. The experimental procedure for measuring pressure is reported in detail in reference 1.

*Rise time for a running detonation depends upon both the traversal time across the width b of the gage and the reverberation equilibration time through the thickness h. Optimum performance for a given gage cross-sectional area is obtained by making these times approximately equal, i.e. by making $b/h = 7$.

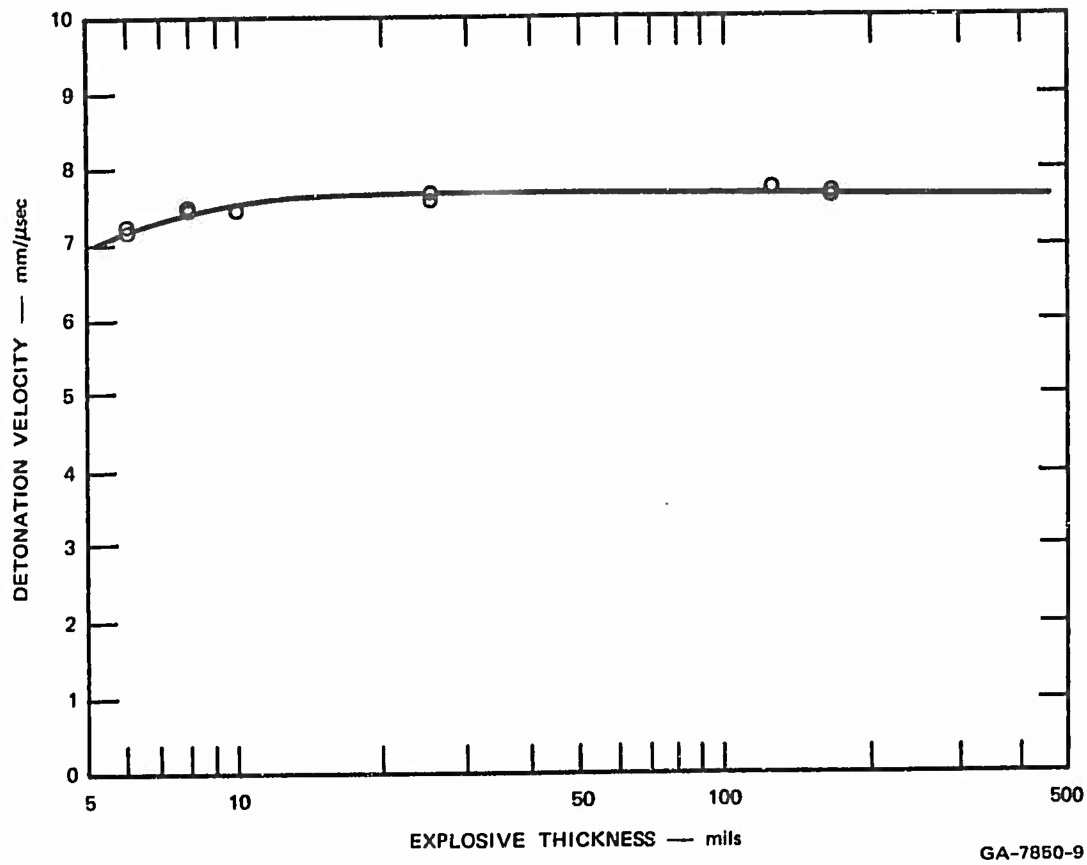


FIGURE 1 DETONATION VELOCITY OF DETASHEET L VERSUS EXPLOSIVE THICKNESS

b. Results

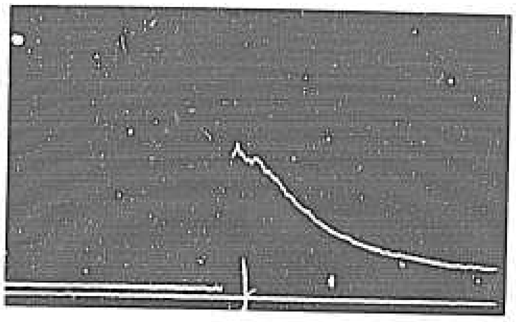
Results of the pressure measurements are summarized in Table II. Typical pressure records from tests of Detasheet D explosive are shown in Figure 2. The peak pressure generated by the thickest (168 mils) Detasheet L explosive tested in direct contact (shown in Figure 2(a)) was 79.1 kbar as compared with about 70 kbar for Detasheet D. These are the highest pressures obtainable with either explosive under a running detonation in contact with typical heat shield materials.

Table II

PEAK PRESSURES FROM DETASHEET L EXPLOSIVE

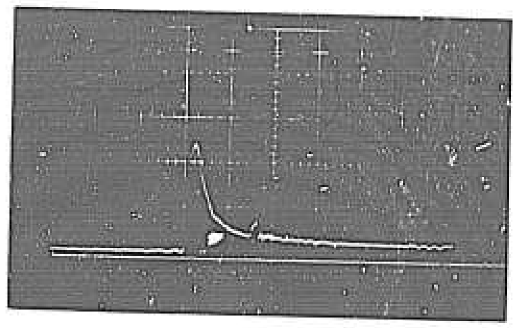
Shot No.	Explosive Thickness (mils)	Solid Neoprene Thickness (inch)	Gage Setback (mils)	Recorded Peak Pressure (kbar)	Extrapolated Peak Pressure (kbar)	Comments
P-2	25	--	10	60.0	--	
P-3	25	--	5	62.1	--	
P-12	85	--	10	74.8	--	
P-1	85	--	10	--	--	Very noisy signal; no continuous trace.
P-15	168	--	40	80.9	--	
P-17	168	--	40	79.1	--	
P-14	168	--	20	--	--	Gage broke; unreliable record.
P-13	168	--	10	--	--	Gage broke; unreliable record.
P-6	10	1/16	10	10.5	15.3	
P-18	10	1/16	10	10.3	--	Too steep to extrapolate.
P-5	10	1/16	10	7.8	--	Explosive not cemented to gage.
P-8	10	1/8	10	9.2	10.5	
P-16	10	1/8	10	8.4	10.1	
P-7	10	1/8	10	6.7	--	Explosive not cemented to gage.
P-4	20	1/16	10	25.8	31.8	
P-9	20	1/16	10	23.2	27.2	
P-11	20	1/8	10	17.1	20.2	
P-10	20	1/8	10	16.9	19.2	
P-19	20	1/8	10	15.2	--	

Although the pressure obtained using 200-mil-thick Detasheet D explosive was constant at the peak value of about 0.5 μsec (Ref. 1), the pressure obtained with 168-mil-thick Detasheet L explosive, after reaching a peak, decreased slightly to an approximately constant plateau for about 0.4 μsec after the pulse arrived at the gage, as shown in Figure 2(a). This difference in recorded wave shape generated by the two types of explosive was attributed to the differences in gage construction, since theoretically the pulse shapes must be similar. To verify this, two of the flattened wire gages were tested using 100-mil-thick Detasheet D explosive. Records from these tests show pulse shapes comparable to the pulse shapes observed



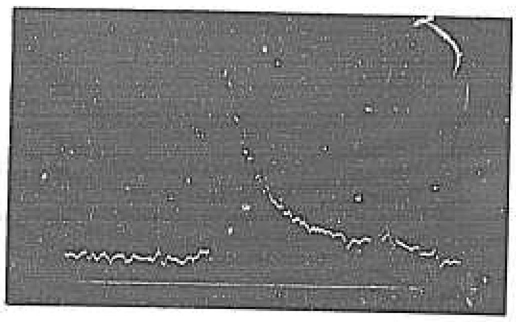
(a) SHOT NO. P-17

168 mils EXPLOSIVE IN DIRECT CONTACT
100 mv/cm, 0.5 μsec/cm, v = 1.35 v
P = 79.1 kbar



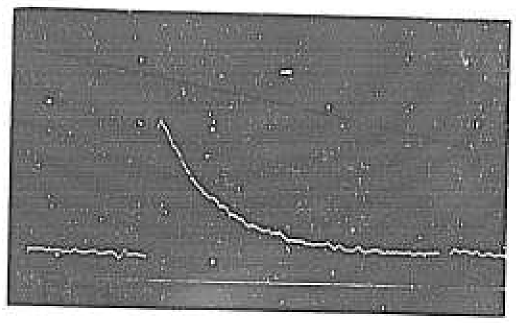
(b) SHOT NO. P-2

25 mils EXPLOSIVE IN DIRECT CONTACT
200 mv/cm, 0.5 μsec/cm, v = 2.755 v
P = 60.0 kbar (ACTUAL ~80 kbar)



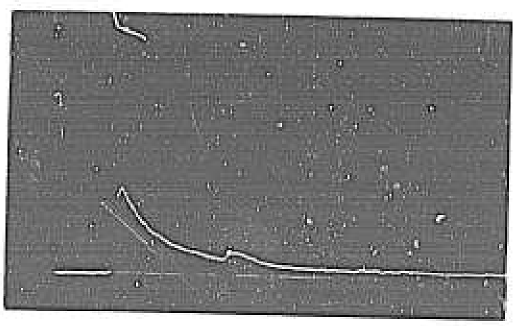
(c) SHOT NO. P-6

10 mils EXPLOSIVE OVER 1/16 inch NEOPRENE
30 mv/cm, 0.5 μsec/cm, v = 2.825 v
P = 15.3 kbar (EXTRAPOLATED)



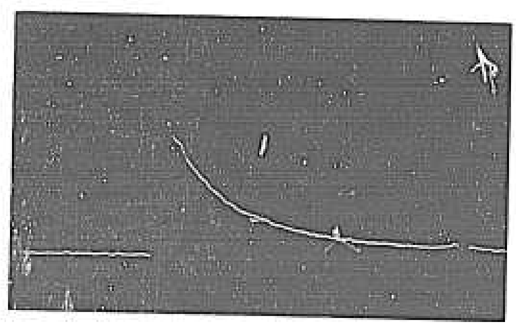
(d) SHOT NO. P-8

10 mils EXPLOSIVE OVER 1/8 inch NEOPRENE
30 mv/cm, 0.5 μsec/cm, v = 2.830 v
P = 10.5 kbar (EXTRAPOLATED)



(e) SHOT NO. P-9

20 mils EXPLOSIVE OVER 1/16 inch NEOPRENE
100 mv/cm, 0.5 μsec/cm, v = 2.705 v
P = 27.2 kbar (EXTRAPOLATED)



(f) SHOT NO. P-11

20 mils EXPLOSIVE OVER 1/8 inch NEOPRENE
50 mv/cm, 0.5 μsec/cm, v = 2.879 v
P = 20.2 kbar (EXTRAPOLATED)

GP 7850 10

FIGURE 2 PRESSURE PULSES FROM DETASHEET L EXPLOSIVE IN CONTACT WITH DOPED EPOXY AND WITH SOLID NEOPRENE BETWEEN THE EXPLOSIVE AND THE EPOXY

with flat-wire gages tested with thick Detasheet L explosive. The peak pressures were 69.0 and 69.7 kbar compared with about 70 kbar previously recorded with round-wire gages. Therefore it is concluded that the peak pressure recorded by the flattened wire gages is correct, but the pressure drop following the peak is caused by the flat-wire construction.

Measurements with the explosive in direct contact with the doped epoxy were also made at the minimum explosive thickness estimated to allow the gage to reach equilibrium at the peak pressure. On the basis of the thickness and the width of the gage, this explosive thickness was estimated to be 25 mils. Results of this test gave a peak pressure of 60.0 kbar, as shown in Figure 2(b). Hence the recorded peak pressure is below the true peak pressure. The shape of the recorded pulse strongly suggests that the gage could not follow the true pressure (compare Figs. 2(a) and (b)). Best estimates of peak pressure for thin explosive sheets are therefore made on the basis of the theoretical result that peak pressure is proportional to the square of the detonation velocity (Ref. 4). Thus, from the velocity data in Table I, at thicknesses above about 10 to 20 mils peak pressure is virtually independent of thickness. In the extreme case, at 6 mils, the data in Tables I and II give a peak pressure $P = (7.22/7.60)^2 (80.5) = 72.7$ kbar.

Pressure records using solid neoprene attenuators are shown in Figures 2(c) through 2(f). The peak pressures shown in the records are slightly inconsistent, as seen in Table II, and the errors appear to be random. This is attributed to the size of the glass beads in the epoxy being comparable to the size of the manganin wire. This effect was not apparent in tests with the thicker explosive in direct contact with the epoxy because the time at peak pressure was longer than the equilibrium time of the gage. Since the glass beads are not uniform in size, the equilibrium time for each gage depends on its distribution of bead sizes near the wire, resulting in a random error in recorded peak pressure. To estimate the actual peak pressures for the tests performed with attenuators, the pressure records were linearly extrapolated back to the arrival time of the pressure pulse, as described in reference 1. The results give peak pressures that are consistent with each other. These

pressures are higher than extrapolated pressures for similar measurements with Detasheet D. Peak pressures for 10- and 20-mil-thick Detasheet L explosives attenuated by both 1/16- and 1/8-inch-thick solid neoprene are shown graphically in Figure 3. For comparison, results are also shown for Detasheet D.

3. IMPULSE MEASUREMENTS

a. Experimental Technique

Impulse was determined by measuring the velocity imparted to 4-inch-diameter target plates by explosive loading. The targets were made of 0.375-inch-thick Grade 79 Micarta* bonded with Epon 934** to 0.1-inch-thick 6061-T6 aluminum. This is the same configuration used in a previous program (Ref. 3) to determine the impulse from Detasheet D. Target velocity was measured by taking radiographs of the target at two accurately known times. The technique is described in detail in reference 4.

In all but two tests the explosive was in direct contact with the Micarta. Under 20-mil-thick explosive in direct contact, the Micarta was found to delaminate causing difficulty in measuring the total momentum of the target. To reduce this difficulty, a 1/16-inch-thick sheet of solid neoprene rubber was placed between the explosive and the target. Results from similar tests on a previous program (Ref. 3) show that an attenuator of this areal density does not alter the momentum imparted to the target within the scatter of the experimental error.

In some tests not all target pieces were visible in both radiographs. For these cases velocity was determined by assuming that the target had been accelerated to peak velocity during the double transit time of a plane wave through the thickness of the target (~ 10 μsec) and that the target was in its initial position up to that time. Impulses calculated using this initial time and position were found to be consistent with impulses calculated when all target pieces were visible in both radiographs.

---

*Trademark of Westinghouse.

**Trademark of Shell Chemical Company.

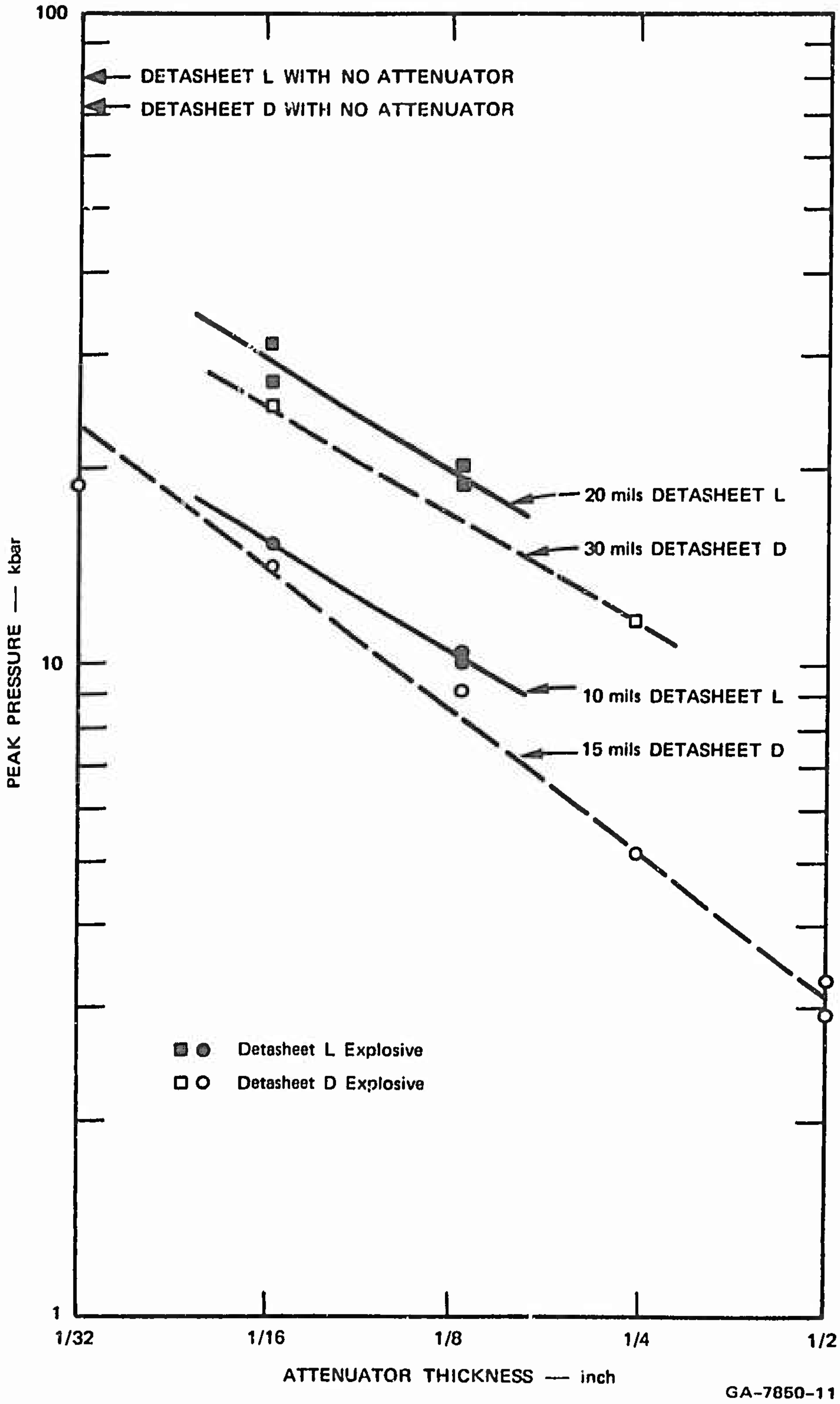


FIGURE 3 PEAK PRESSURE VERSUS SOLID NEOPRENE ATTENUATOR THICKNESS FOR DETASHEET L AND DETASHEET D EXPLOSIVE

b. Results

Results of the impulse measurements for explosive thicknesses of 6, 10, and 20 mils are shown in Table III. The results show that the specific impulse for Detasheet L is about 755 taps/mil at all impulse levels, compared with about 650 taps/mil for Detasheet D. However, since Detasheet L will detonate at a thickness of 6 mils, the minimum impulse obtainable from a continuous sheet is about 6 x 755 = 4530 taps compared with the minimum impulse obtainable with Detasheet D of about 7800 taps.

Table III

IMPULSES FROM DETASHEET L EXPLOSIVE

Loading			Impulse				
Shot No.	Explosive Thickness (mils)	Solid Neoprene (inch)	$I_{Micarta}$ (taps)	I_{alum} (taps)	I_{total} (taps)	I_o (taps/mil)	I_o(ave) (taps/mil)
M-13	6.5	--	1400	3,550	4,950	762	
M-14	6.5	--	1760	3,330	5,090	782	765(3)
M-18	6.5	--	1910	2,960	4,870	749	
M-6	10	--	2080	5,570	7,650	765[a]	
M-7	10	--	1940	5,420	7,360	736	745(3)
M-8	10	--	2120	5,390	7,410	741	
M-15	20	--	4140	10,810	14,950	747[b]	
M-16	20	1/16	4480	10,630	15,110	756[a]	760(3)
M-17	20	1/16	4049	11,270	15,319	767	

[a] Micarta pieces were not all visible in radiograph 1.

[b] Aluminum base was not visible in radiograph 2.

SECTION III

CONCLUSION

The minimum impulse obtainable from a continuous sheet of Detasheet L explosive is about 4500 taps compared with about 7800 taps from Detasheet D. The detonation velocity, pressure, and specific impulse of Detasheet L are only slightly higher than those of Detasheet D. The L explosive is considerably more difficult to roll into thin sheets (takes more passes) than Detasheet D explosive. However, this difficulty is associated with the stiffer binding material in the L explosive, which gives the compensating advantage that even in very thin sheets the L explosive has little tendency to stretch during handling. Thus, Detasheet L has its greatest advantage in very thin, dimensionally stable sheets for low impulse testing. It can also be used in thicker sheets for higher impulse testing, but at these levels the D explosive has the advantage of being easier to roll.

REFERENCES

1. Lindberg, H. E., Colton, J. D., Sheet Explosive Simulation for Combined Shock and Structural Response, AFWL-TR-69-124, Air Force Weapons Laboratory, Kirtland AFB, NM, September 1970.

2. Cook, M. A., The Science of High Explosives, Reinhold, 1958.

3. Lindberg, H. E., Sliter, G. E., Response of Reentry-Vehicle-Type Shells to Transient Surface Pressures, AFWL-TR-68-56, Air Force Weapons Laboratory, Kirtland AFB, NM, June 1969.

4. Abrahamson, G. R., (U) Techniques for Simulating X-Ray Impulses on Reentry Vehicles, Air Force Special Weapons Center, Kirtland AFB, NM, March 1961. (Secret-RD)

This page intentionally left blank.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Stanford Research Institute Menlo Park, California 94025	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

MEASUREMENT OF PRESSURE, IMPULSE, AND DETONATION VELOCITY FOR DETASHEET L EXPLOSIVE

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
November 1970 through January 1971

5. AUTHOR(S) *(First name, middle initial, last name)*

J. D. Colton

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1971	20	4

8a. CONTRACT OR GRANT NO. F29601-69-C-0080	9a. ORIGINATOR'S REPORT NUMBER(S) AFWL-TR-71-23
b. PROJECT NO. 5710 c. Subtask AA122 d.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* Contractor report no. PYU 7850

10. DISTRIBUTION STATEMENT
Each transmittal of this document outside the agencies of the US Government must have prior approval of AFWL (SRR), Kirtland AFB, NM. Distribution is limited because of the technology discussed in the report.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY AFWL (SRR) Kirtland AFB, NM 87117

13. ABSTRACT

(Distribution Limitation Statement No. 3)

Tests were conducted to measure the impulse and pressure characteristics of Detasheet L explosive. Results of these tests show a maximum detonation velocity of 7.6 mm/μsec, a minimum detonation thickness of 6 mils, a peak pressure in direct contact with silica phenolic (simulated by doped epoxy) of about 80 kbar, and a specific impulse of 755 ± 15 taps/mil. The minimum impulse generated by a continuous sheet of Detasheet L explosive is about 4500 taps compared with about 7800 taps (12 mils) for Detasheet D. The L explosive is considerably more difficult to roll into thin sheets (takes more passes) than Detasheet D explosive. However, this difficulty is associated with the stiffer binding material in the L explosive, which gives the compensating advantage that even in very thin sheets the L explosive has little tendency to stretch during handling. Thus, Detasheet L has its greatest advantage in very thin, dimensionally stable sheets for low impulse testing. It can also be used in thicker sheets for higher impulse testing, but at these levels the D explosive has the advantage of being easier to roll.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Explosive shock simulation Sheet explosive Impulse measurement Manganin pressure-time measurement						